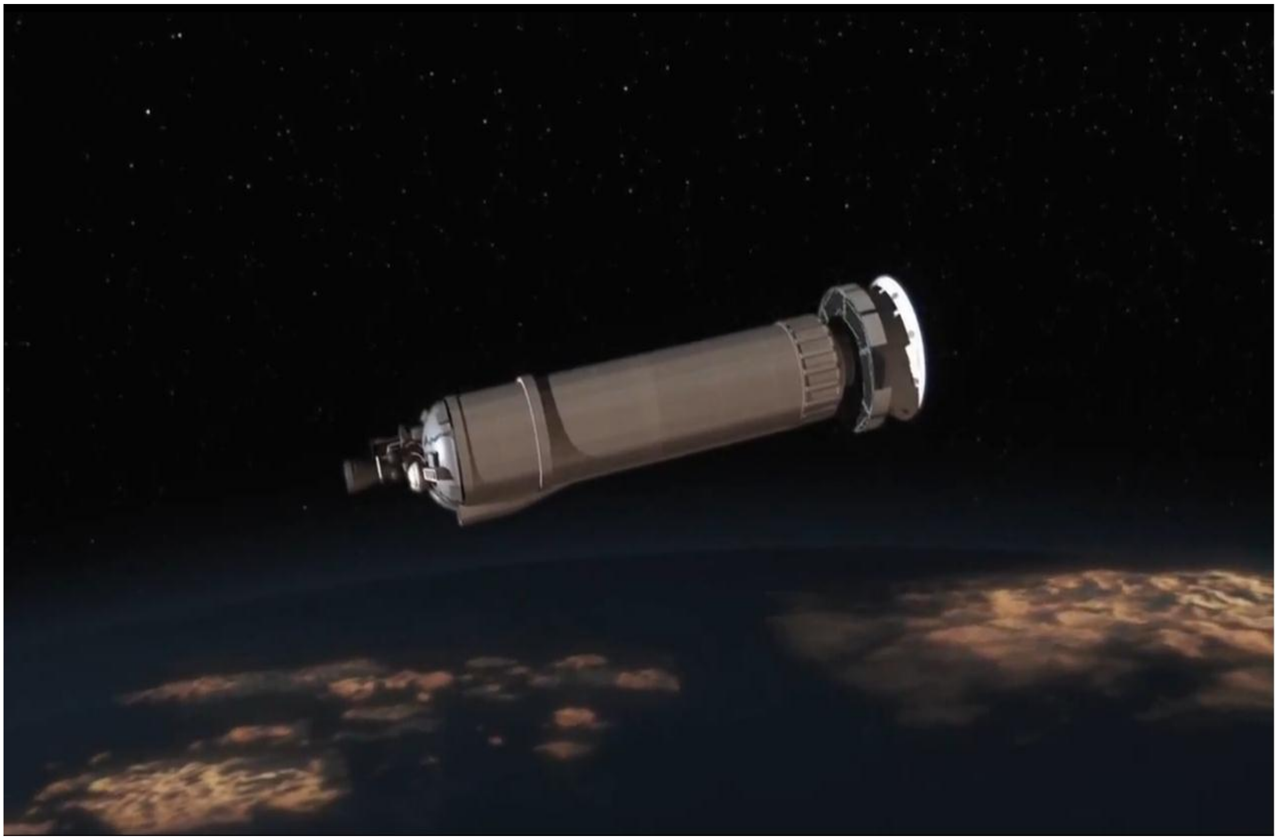
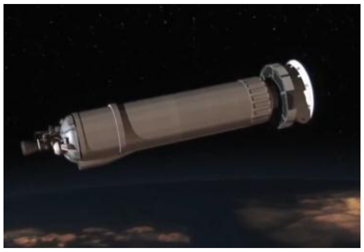
Centaur 50th Anniversary Design Challenge
"Pushing the Limits"



Facilitation Guide

Celebrating Fifty Years of the Centaur Upper-Stage Rocket
1963-2013



Centaur 50th Anniversary Engineering Design Challenge "Pushing the Limits"

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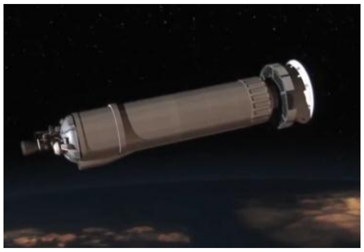

Centaur 50th Anniversary
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Centaur: America's Workhorse in Space

This excerpt taken from http://www.nasa.gov/centers/glenn/about/history/centaur.html

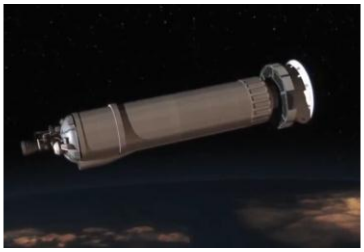
A high-energy rocket is largely responsible for advancing the quest for knowledge and revolutionizing global communications. Its name is Centaur, and it is America's Workhorse in Space. Centaur (*full scale model pictured at left*) is one of NASA Lewis' (now NASA Glenn) most significant achievements. Centaur has been used to boost satellites into orbit and propel probes into space. It has helped to revolutionize communication and expand the frontiers of space. In all, Lewis used Centaur for more than 100 unmanned launches.

The Genesis of Centaur

In 1957, almost one year before Congress created NASA, the Air Force studied an exhaustive proposal from General Dynamics/Astronautics Corp. to develop a new space booster that could give the U.S., in the shortest possible time, a means of orbiting heavy payloads. That vehicle was to become Centaur, a high-energy second stage with a new propulsion system using liquid hydrogen. Mixed with liquid oxygen, this new fuel afforded the promise of boosting payloads as great as 8,500 pounds.

By August of 1958, the Government's Advanced Research Products Agency accepted from the Air Force a more elaborate proposal for the Centaur and assigned authority for its development to the Air Force.

Centaur promised new muscle in space. The U.S. needed it. The Soviet Union had taken the lead with the very first space flight; Sputnik I launched into Earth orbit on October 4, 1957, its "Bleep, Bleep" being heard around the world. Centaur became an official hardware development program the same year NASA was established, in 1958. At that time, the heaviest Soviet satellite orbiting Earth was the 3,000-pound Sputnik III.



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Reflecting long-range U.S. space strategy, on July 1, 1959, NASA took over the jurisdiction of Centaur from the Department of Defense. Soon after, the first Centaur flight test was set for January, 1961. Centaur was not to be just another booster, but the rocket by which NASA would conduct extensive Earth orbit missions, lunar investigations and planetary studies. Aside from military satellite missions assigned to Centaur, which were to be considerable, NASA planned to launch one operational Centaur every month for a period extending well into the 1970's and beyond.

That schedule became hopelessly over-optimistic, dogged by an avalanche of problems, failures, test-stand explosions and other delays. On May 8, 1962, the first Centaur rose, a perfect launch for the first 54 seconds. Then, the Centaur upper stage exploded. DoD officials became convinced that operational Centaurs would not be available until 1966.

NASA rescheduled another flight test for October, 1962. Now, Dr. Abe Silverstein stepped forward and convinced the hard-pressed NASA organization that his Lewis Research Center could debug and manage the problem-ridden Centaur. Full responsibility was assigned to Lewis under Dr. Silverstein, its second Director.

Engineers at Lewis were familiar with the Centaur's liquid-hydrogen/liquid-oxygen cryogenic fuels, having developed the technology for safe handling of the -400 degrees F propellants. Long before NASA was created, Lewis conducted pioneering work on the high-energy liquid propellants for rockets. This included, in the late 1940's, accumulating valuable test data that became the technical base for the space age. Successful tests produced the ramjet and rocket technology that were later to carry men and machines at incredible speeds through the atmosphere and beyond.

Given a go-ahead, Lewis engineers perfected the workhorse booster, carrying out a complex research and development program to assure its reliability. To make certain of Centaur's success, the Lewis team also perfected and improved the Atlas booster, which would carry it off the pad. Special facilities were set up for ground testing both rockets at Lewis' Plum Brook Station in Sandusky, Ohio.

Finally, on November 27, 1963, it happened. NASA had its first successful launch of the first Atlas/Centaur. No payload was carried, but the powerful rocket scored a significant milestone: first in-flight burn of a liquid-hydrogen/liquid-oxygen engine. Major successes followed rapidly.

From Blueprints to the Pad

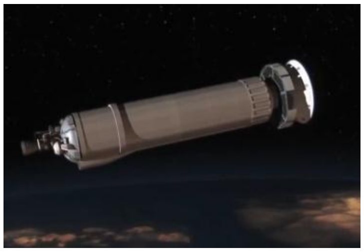
The Centaur rocket was this nation's first high-energy upper stage launch vehicle. Most rockets burn kerosene based hydrocarbon fuels, but the Centaur uses a liquid-hydrogen/liquid-oxygen propellant combination. The high energy provided by this combination results in a greater specific impulse for the rocket. This means more thrust or pushing force is provided for each pound of propellant burned every second. Specific impulse for a rocket is somewhat like miles per gallon of a car as a measure of fuel efficiency. This is important, since the weight of the propellant is a large part of the total weight of a rocket system.

The original Centaur rocket measures 30 feet long and 10 feet in diameter. Fully fueled it weighs more than 35,000 pounds. Use of the high-energy propellant combination on the Centaur meant heavier payloads could be carried into orbit. Payloads weighing as much as 5,000 pounds could be carried to high Earth orbit in combination with the Atlas first stage.

At General Dynamics in the San Diego area, the Centaur was assembled. Because the Centaur rocket used very cold propellants, the tanks require special construction. The tank was separated into two compartments. One contained liquid hydrogen and the other liquid oxygen. At -297 degrees Fahrenheit, liquid oxygen is extremely cold but still much warmer than the -420 degree temperature of liquid hydrogen. To prevent the liquid hydrogen from boiling off, General Dynamics designed a double walled bulkhead, which serves as a heat barrier. It also acts to separate the two compartments.

The liquid hydrogen compartment is covered with lightweight insulation. It protects the tank from the intense aerodynamic heating experienced during the rocket's flight through the earth's atmosphere. The insulation prevents further boil off of the cold fuel inside the tank.

The tank must be built to withstand the stresses of flight. The tank is made of very thin stainless steel, less than 200ths of an inch thick, or thinner than a dime. Although the tank is extremely thin, once pressurized, it is lightweight, yet rigid like a football.



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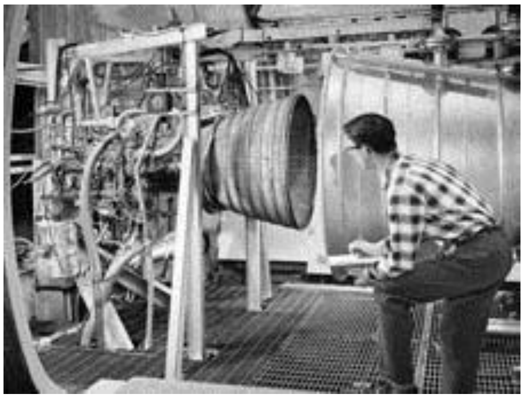


The rocket is equipped with two main engines. Designed by Pratt & Whitney Aircraft, each RL-10 engine (*pictured in development at left*) produces 16,500 pounds of thrust for a total of 33,000 pounds. Many liquid fuel rockets burn some fuel to run a fuel pump but with the RL-10 engines this step is eliminated, thereby conserving fuel, which instead can be burned to produce added thrust.

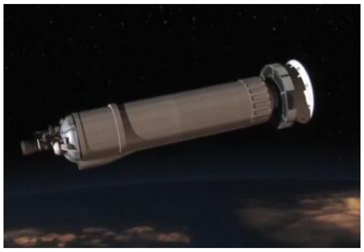
The RL-10 has proven to be a very successful engine. It was the forerunner of the liquid-hydrogen/liquid-oxygen class. The technology was incorporated into the J-2 engines which were used on the upper stage of the Saturn rocket for the Apollo. The technology has also been utilized in the Space Shuttle Main Engine, which use liquid hydrogen and liquid oxygen.

Another important feature of the RL-10 engines is that they are capable of making multiple starts after long coast periods in space. The advantage is accuracy. It's like an outfielder in baseball trying to throw a base runner out at home plate. By throwing the ball to an infielder who relays the ball to the catcher at home plate, the ball is given a mid-course correction. The result is improved accuracy compared to one long throw from the outfield. When the target is 3 billion miles away instead of 300 feet away, the accuracy is that much more important.

Besides the two main engines, which produce the thrust to power the Centaur, several other small thrusters are fired to steer the rocket. These small thrusters are part of the Reaction Control System, or RCS. The RCS maneuvers the rocket in response to commands given by the Guidance and Control System.

All of the components including the propellant tanks, engines, navigation and computer systems are thoroughly tested. Reliability and quality must be guaranteed before a rocket is committed for use on a space flight.

Assembly of the rocket system was done at General Dynamics in San Diego. After passing final acceptance inspection, the assembled rocket was shipped to the eastern test range at Cape Canaveral Air Station.



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Upon arrival at the Cape, engineers and technicians perform ground tests and operations to ensure the rockets reliability. First, Centaur is moved to a hanger for receiving inspection. If all is well, the rocket is then taken to the launch complex where more testing is done. Additional testing and inspection is necessary to assure that the rocket is in perfect operating condition. The slightest malfunction could cost the entire mission. Because the Centaur operates with a first stage, integration tests must be conducted to make certain that the two stages are compatible.

When everything checks out, the rocket is prepped for launch. The entire testing procedure takes weeks to complete.

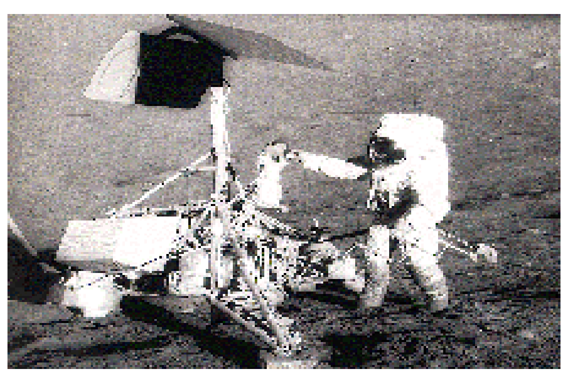
About four days prior to launch, the Lewis rocketeers would form a tiger team of specialist down at the Cape. Numbering some 30 experts -- they also form the launch team itself -- they would do a walk-down inspection of the mated rockets on the pad. Starting at the top, they would come down the gantry and do a complete inspection, using a checklist of what to look for in addition to the normal procedures.

The tiger team subsequently would run through a demonstration countdown, do a simulated mission to check all software and test the engines to within one second of liftoff. Then they would put the rocket back into start condition for the flight.

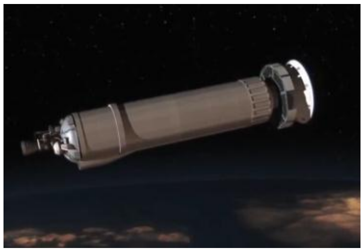
At the point of launch itself, we monitored everything. Kennedy personnel or contractors who had built the equipment actually sat at the control consoles and pushed the buttons, but the Lewis team made the decisions. After a final status check, the final call would be made: "Go Atlas! Go Centaur!"

Go Atlas! Go Centaur!

For almost 30 years, Lewis was responsible for the technical and cost and schedule management of the Centaur rocket. During that period of time many changes were made that have evolved the Centaur rocket into a workhorse for NASA.



This program, since its first launch, has had an extraordinary operational success record. It was developed as an upper stage launch vehicle to be used with a first stage booster rocket, the Atlas



rocket. Centaur's first mission objective was to send the unmanned Surveyor spacecraft to the Moon (*shown at its landing site on the Moon at right*). In preparation for the Surveyor mission, eight experimental flights were conducted during a four year period. Technological improvements were made after each test flight.

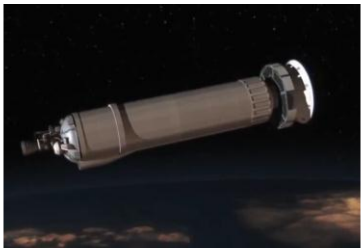
Perhaps the worst moment in the Centaur program probably came in 1965 with the explosion on the pad with the AC-5 development flight. The vehicle and the pad were lost. The challenge was to find out what went wrong, correct it, and successfully complete that portion of the program.

In May of 1966, Surveyor 1, an unmanned lunar spacecraft was launched. It was our first soft lander on the moon. Surveyors collected data on the moon's surface texture and provided high resolution photographs of the surface. This knowledge was vital to the success of the later Apollo manned lunar landing missions.

In the 1970's, Centaur was combined with the Air Force Titan III booster to provide a capability to launch larger spacecraft. Together, with Atlas and Titan boosters, Centaur served as the upper stage for probes and fly-by's to other planets, to Mercury, Venus, Mars, Jupiter, Saturn, Uranus, and Neptune. The Mariner, Pioneer, Viking and Voyager spacecraft have provided invaluable data on these planets.

Close up pictures of Mars and information gathered by the spacecraft instruments, have enabled us to study the planet's weather and the nature of its atmosphere. High resolution pictures sent to us by Voyager on its Grand Tour surprised us with worlds of unexpected complexity. These findings may help explain the unique features of these planets and answer questions about their evolution and about the origins of our solar system.

Centaur launched orbiting observatories to study space beyond our solar system in the search for knowledge about the universe. The Orbiting Astronomical Observatories, or OAO's, were launched in the late 1960's and early 1970's. OAO discovered a hydrogen cloud one million miles in diameter surrounding a comet. This was the first observational evidence that such clouds exist. OAO also observed extragalactic nebulae and the ultraviolet region of the electromagnetic spectrum, observations not possible from earth. In the late 1970's the high energy, orbiting, astronomical observatories, or HEAO's surveyed the heavens to pinpoint sources of cosmic and gamma rays.



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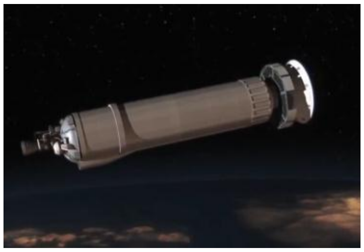
Centaur has launched various communications satellites into geo-synchronous orbit, 22,000 miles above the earth. The Application Technology Satellites, or ATS, were launched in the late 1960's, this was followed by INTASAT, Comstar, and FLTSATCOM satellites throughout the '70's and '80's. These satellites are key links in the world's communication network.

A Partnership with Industry
Private industry has provided engineering and support activities since the initial development. Companies such as General Dynamics Corporation, Teledyne, Pratt and Whitney Aircraft and Honeywell Incorporated, have worked in cooperation with NASA in designing and improving this launch vehicle.

Today, rather than managing the design, development, and launch operations, NASA procures commercial launch services. NASA Lewis continues to support industry by developing and testing new technologies and hardware through cooperative programs.

A new era began the launch of the Combined Release and Radiation Effects Satellite on a commercial Atlas I in July of 1990. Centaur has also helped launch several GOES weather satellites. Centaur continues to support scientific missions such as SOHO, which launched on Atlas/Centaur-121 on December 2, 1995. This was NASA's first use of this commercial version of the Atlas IIAS rocket. Centaur flew again on top of a Titan booster in October 1997 to launch Cassini on its way to Saturn.



Centaur 50th Anniversary
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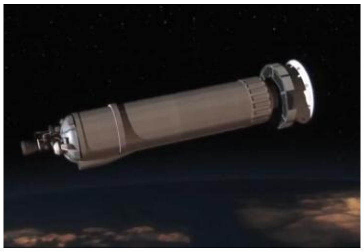
Facilitator Notes

The Challenge:

Students will design and build a self-propelled vehicle that uses air pressure (propellant) contained in a common rubber balloon that can transport a single removable payload (25 gram weight) as it travels along the ground on a "Challenge Field Map" from a "Launch Site" to a " Mid-point area", and then to a final "Rendezvous Point". During the traveling process the self-propelled vehicle will be required to come to a complete stop in order to make a mid-course directional correction. After the vehicle has made its mid-course correction it will need to restart and propel itself to the final Rendezvous Point on the challenge field map.

Procedure:

- **Prepare ahead of time**
  - Read the following documents to become familiar with the design challenge components.
    - Student Design Challenge Guide (page 14)
    - Student Data Sheet (page 17)
    - Challenge Field Map Specifications (page 19)
    - Engineering Design Process (page 20)
    - Written Component Guidelines (page 22)
    - NASA Education Pre/Post-Assessment (page 24)
  - Review the Optional Classroom Activities and Resources listed on page 28. Gather the required materials listed on the "Student Design Challenge Guide" and any other supplies the teams may be able to use for their vehicles.
  - Create teams of four to six students
- **Introduce the challenge** (15 minutes)
  - Explain to students the importance of taking the knowledge learned in the Rocket Races Activity (link found on page 28) to design and create a propulsion vehicle that meets the requirements of the Centaur design challenge.
  - Discuss with students the importance of Centaur's ability to stop mid-course and change direction, with the overall goal of reaching the final rendezvous point as close to the bull's-eye as possible.(See field map on page 19).
  - Explain the purpose of reaching the mid-course target area and also the reason for restarting the vehicle to reach the final rendezvous point.
  - Brainstorm possibilities of approaches to reach the mid-point area and the rendezvous point as a class.



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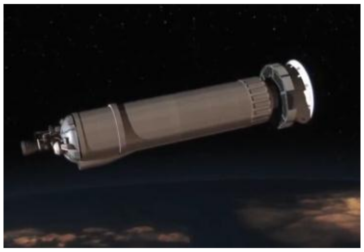
- **Student Team Work**
  - Suggested positions for members: Design Engineer, Writing Engineer, Research Engineer, Technical Engineer, Operations Engineer (Positions defined on page 16)
  - Create a field map outline on the floor by using a tape measure and masking tape to a rectangular dimension of 5 ft. by 12 ft. (See field map on page 19).
  - Teams design, construct, and test through trial and error, a vehicle which meets the specified challenge requirements
  - Teams record the changes and or modifications that are made to vehicle throughout the engineering design process, including why the changes were required, what changes were made, and what was the outcome of the changes.

- **Report Out**
  - Teams report their designs and what they have learned with a tri-fold poster presentation including a 500 word essay on their team designs and modifications, and how the teams design relates to Centaur. (See Tri-fold guidelines on page 22).



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National Standards Alignment

Ohio Revised Science Standards and Model Curriculum

Forces and Motion: Forces have magnitude and direction.

Forces can be added. The net force on an object is the sum of all the forces acting on the object. The net force acting on an object can change the object direction and/or speed

Next Generation Science Standards:

Motion and Stability: Forces and Interactions

MS-PS2-2: Plan and investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

MS-RST.6-8.3: Follow precisely a multi-step procedure when carrying out experiments, taking measurements, or performing technical tasks.

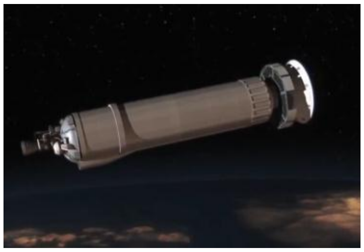
Engineering Design

ETS1-4: Develop a model to generate data for interactive testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into a smaller, more manageable problem that can be solved through engineering.

Student Learning Objectives/Targets:

- Students will be aware of the history of the Centaur Rocket as it relates to the 50^{th} Anniversary celebration, including how Centaur's development affects the 21^{st} century space travel.
- Students will discuss the process of creating their propulsion design, how it was created, challenges that arose during the engineering process, how their team worked together to re-design and re-test their systems, as well as discussing the success of their final product.



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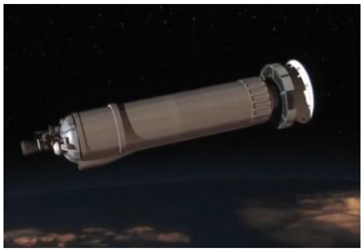
- Students will learn about the "Engineering Design Process" (See page 20) which is common to the engineering field. This in turn will give the students an understanding of how everyday products are designed and fabricated, along with the research that is performed to create a final product from a simple idea.



Centaur 50th Anniversary
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Student Design Challenge Guide

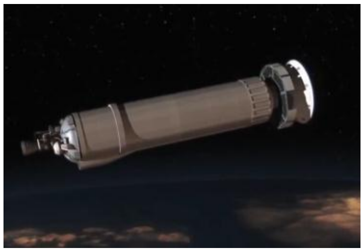
The Challenge:

Students will design and build a self-propelled vehicle that uses air pressure (propellant) contained in a common rubber balloon that can transport a single removable payload (25 gram weight) as it travels along the ground on a “Challenge Field Map” from a “Launch Site” to a “ Mid-point Area”, and then to a “Rendezvous Point”. During the traveling process the self-propelled vehicle will be required to come to a complete stop in order to make a mid-course directional correction. After the vehicle has made its mid-course correction, it will need to restart and propel itself to the final Rendezvous point on the challenge field map**.**

- **Required Materials:** Various construction and or art supplies (no restrictions)
- Balloons (Any type or size allowed)
- 3-ounce Paper Cup (I.e. Dixie cup)
- Paper Clips
- Pencil
- Tape measure
- 5-foot by 12 - foot floor space
- Other various materials to construct the following rocket vehicle components
    - Wheels and Axles
    - Payload framing
    - Connector/attachment for propellant containers (balloons) onto vehicle
    - Starting and/or stopping mechanisms

Design Challenge Rules:

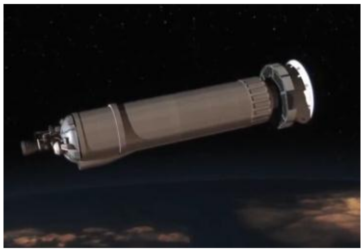
1. The vehicle must be able to self-propel itself with the use of a common rubber balloon/s.
2. The rubber balloon is to be used as a “propellant container” which can be any size, shape or length.
3. Rubber balloons are the **ONLY** type of containers that will be allowed for propellant storage and can only be filled with human or canned air.
4. No other types of propellant containers other than rubber balloons are permitted.
5. There is no limit to the number of rubber balloons used on or about the vehicle.
6. The vehicle must be able to carry a single **removable** payload which consists of a standard 3-oz Dixie cups filled with paperclips weighing a total of 25 grams.*
7. Vehicle must be able to start from the “Launch Site” and propel itself to the specified mid-point area which it will need to come to a complete stop.
8. Once the vehicle has made a complete stop at the mid-point area, the vehicle will need to be rotated towards the “Rendezvous Point”. This rotation can be done



by a single student lifted the vehicle and manually turning it towards the Rendezvous Point, or the vehicle can be operated by remote control, but **“ONLY to rotate”** the vehicle. Teams who can rotate their vehicle without touching it with human hands will receive bonus points towards their overall score.

9. In the case that a student will need to manually rotate the vehicle, a marker will be placed on the field map to designate the mid-point starting position.
10. The vehicle is **NOT** allowed to have any robotic components that will propel the vehicle in any way. Using robotics with propel capabilities will be disqualified.
11. Once the vehicle has made its mid-course correction, it must re-energize and re-start its propulsion system and travel to the “Rendezvous point” which will be marked by a three-ringed bulls-eye.
12. Points will be given to teams according to where the “payload” is located over the bulls-eye. The vehicle’s payload must land within the three-ringed bulls-eye to obtain points for their team.
13. Teams will have two chances to propel their vehicle from the “Launch Site” to the “Rendezvous Point”. The top score of the two matches will be used towards their final overall Challenge score.
14. The vehicle cannot be larger than 15cm width by 25cm length, and has no restrictions for its height. These dimensions are solely for the vehicle and do not include the size of the balloon.
15. The vehicle may be constructed out of any material/s and has no weight restrictions.

* Note: A pre-weighed payload will be provided for teams to use at the formal Design Challenge Event



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Definitions:

Challenge Field Map – A 5' x 12' playing field with a specified "Launching Site", "Mid-point area", and "Rendezvous Point" (Bulls-eye area).

Design Engineer – A designated person who takes responsibility to work out the structure or form of something, as by making a sketch, outline, pattern, or plans with the input of his/ her team members.

Energize – To prepare the propulsions system by filling a rubber balloon/s with the proper amount of air to transport the vehicle and payload to a desired point on the field map.

Payload- The load carried by a vehicle exclusive of what is necessary for its operation. The payload for this design challenge will be a 3-ounce paper Dixie cup filled with any type of paperclips but with a specified total weight of 25 grams.

Propellant Container – A rubber balloon of any size, shape or length.

Launch Site – Location where air-propelled vehicle will start its journey.

Mechanism - A system of parts that operate or interact like those of a machine.

Mid-point Area – An open area on field map where vehicle will need to make its directional correction prior to being propelled to the Rendezvous Point.

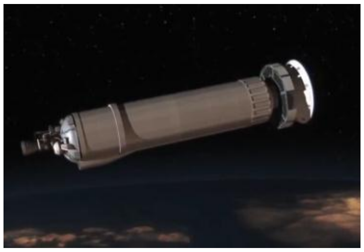
Operations Engineer- A designated person who takes responsibility to setup and operate any mechanical or electrical systems required to complete a process.

Rendezvous Point – The final location where the air-propelled vehicle needs to end its journey. The rendezvous point will contain a three-ringed bulls-eye target that will determine how many points a team will receive depending on where the center of their payload lines up with the bulls-eye rings.

Research Engineer- A designated person who takes responsibility to improve and develop various products and/or processes after performing research on past and present methods of similar or new concepts.

Technical Engineer- A designated person who takes responsibility to assemble, maintain, repair or modify mechanical or electrical components of the overall system.

Writing Engineer- A designated person who takes responsibility to collect data, to capture details about the data, create an outline for the work to be presented, and to work with the input provided by his/ her team members.



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Name____ Date _________________

STUDENT DATA SHEET

Centaur Design Trial # ______

Brief description of design:

____

____

Describe how your team's design worked.

____

____

Was the vehicle able to stop on its own while remaining on the playing field?
____

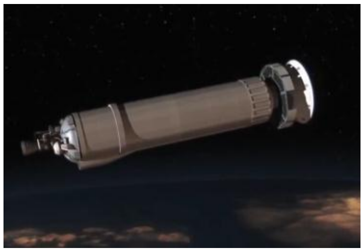
Was the vehicle able to make a mid-correction manually? ___________

Was the vehicle able to make a mid-correction without a team member touching the Vehicle (Autonomously)? ________ (Optional)

Was the vehicle able to be re-energized with propellant at the mid-point?
Position? __________

Was your team able to restart the vehicle at in the mid-point area? _________

Was your team able to get their vehicle within the bulls-eye area??__________________



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Was your team able to get their "payload" over one of the bulls-eyes rings? If so which one? Center___ Middle ____ or Outer ring? _______________

If not, by how many centimeters was the vehicle off (Measure from the center of the payload to the nearest Bulls-eye line.)? __________cm

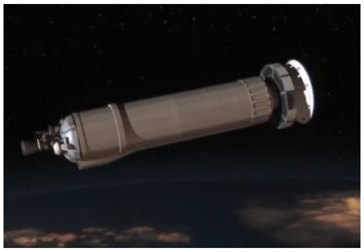
What and how will you try to improve your Centaur vehicle after this trial?

____

____

____

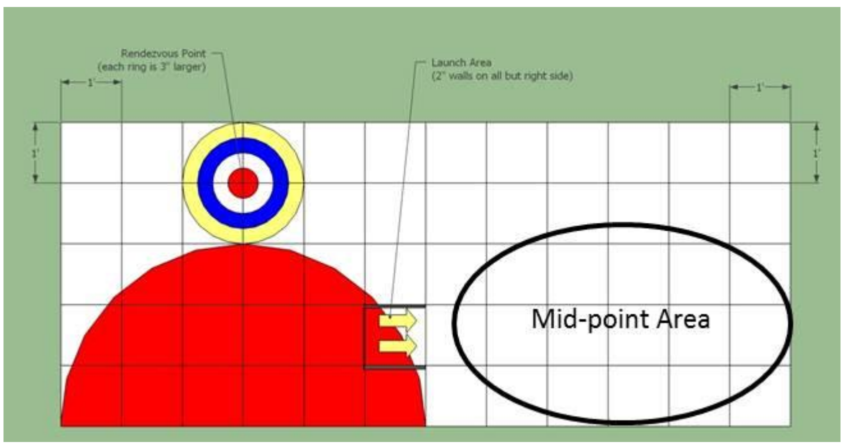
In the space below, sketch any vehicle modifications you will make for the next trial.

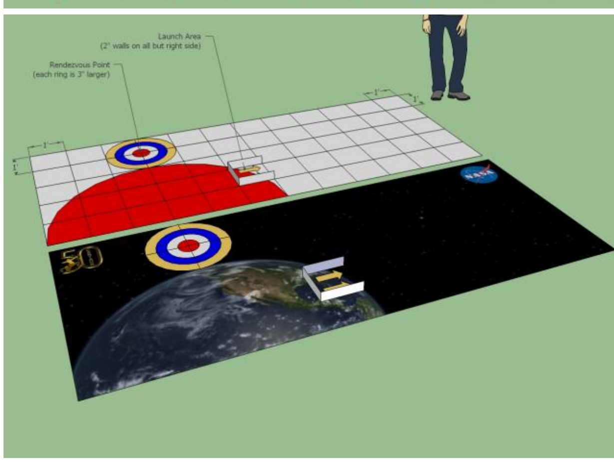


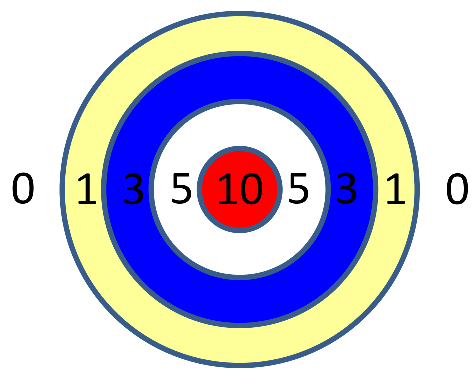
Centaur 50th Anniversary Engineering Design Challenge "Pushing the Limits"

Challenge Field Map Specifications

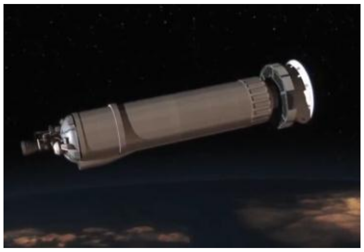
To set up the challenge field, you will need a 5-foot by 12-foot floor space. It can be helpful to create a 1-foot by 1-foot grid. Often, school floor tiles are 1-foot squares. Use tape (masking or electrical work well on floors) to mark the rectangular boundaries as shown below. The 2-inch walls shown around the launch area can be made from cardboard. The walls serve as a way to force the vehicle in the opposite direction of the rendezvous point so that the vehicle must change direction mid-course to reach the final target.







The top image will provide a guide to lay out the Challenge Field. The bottom image simulates the field that will be used at the Engineering Design Challenge Event. The Bulls-eye shows the possible scores that will be given depending on the final position of the actual payload when the vehicle stops.



Centaur 50th Anniversary
Engineering Design Challenge
"Pushing the Limits"

Engineering Design Process

The engineering design process involves a series of steps that lead to the development of a new product or system. In this design challenge, students are to complete each step and document their work as they design their air-propelled Centaur vehicle. The students should be able to do the following:

STEP 1: Identify the Problem -- Students should state the challenge problem in their own words. Example: How can I design a __________ that will __________?

STEP 2: Identify Criteria and Constraints -- Students should specify the design requirements (criteria).What needs to be included: What are specifications or rules that the design has to abide to. Students should list the limitations of the design due to available resources and the environment (constraints).

STEP 3: Brainstorm Possible Solutions -- Each student in the group should sketch his or her own ideas as the group discusses ways to solve the problem. Labels and arrows should be included to identify parts and how they might move. These drawings should be quick and brief.

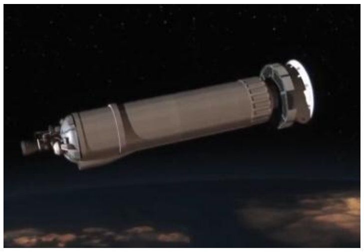
STEP 4: Select a Design -- Students will share their designs within their group and discuss positive and negative aspects of each. They will choose a design to begin, possibly implementing aspects of several designs into one.

STEP 5: Build a Model or Prototype -- Students will construct a full-size or scale model based on their selected designs. The teacher will help identify and acquire appropriate modeling materials and tools.

STEP 6: Test the Model and Evaluate -- Students will repeatedly test their solution in a controlled test environment. They will take measurements and observations regarding each test and begin to consider modifications that may address any issues with the design that arise while testing. (Use Student Data Sheet)

STEP 7: Refine the Design -- Students will examine and evaluate their prototypes or designs based on the criteria and constraints given in the challenge rules. Groups may enlist students from other groups to review the solution and help identify changes that need to be made. Based on criteria and constraints, teams must identify any secondary problems and proposed solutions.

STEP 8: Share the Solution -- Students will demonstrate their solution in a tri-fold poster presentation and within the classroom that will allow them to show knowledge and skills gained from utilizing the engineering design process to solve the initial problem.



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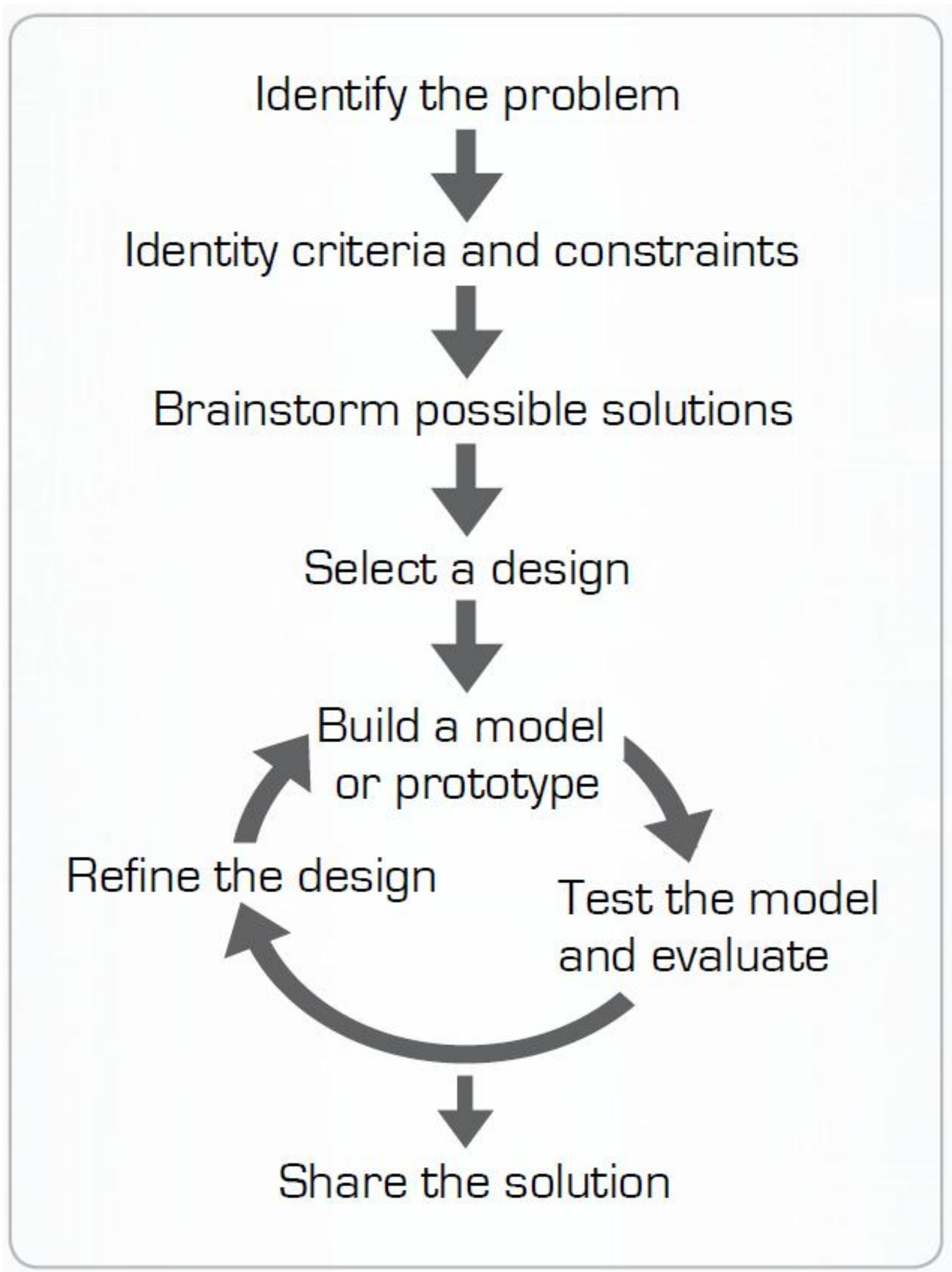
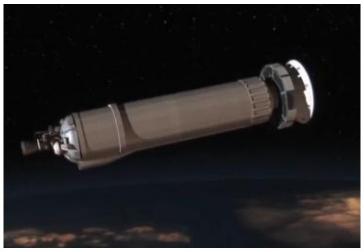
Engineering Design Process





Centaur 50th Anniversary
Engineering Design Challenge
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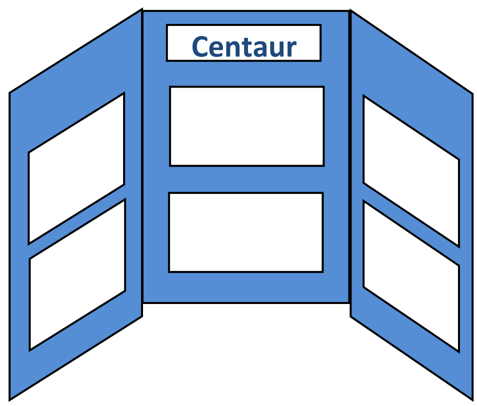
Written Component Guidelines

Students will be evaluated on a written component along with the performance of their Centaur vehicle. Each group is required to create a tri-fold poster board including aspects of the Engineering Design Process along with a 500-word (maximum) essay about the significance of the Centaur rocket.

Tri-Fold Poster

The Tri-Fold poster board is used to share the team's process in creating, constructing and testing their engineering design. The poster should be clean and organized, and include the following information

- An appropriate title
- A section highlighting the work the team did to complete each step of the Engineering Design Process
- Visual aids, including photos or illustrations showing the development of the design, charts and/or tables presenting test data, and lessons learned from the entire design process.
- Centaur Essay

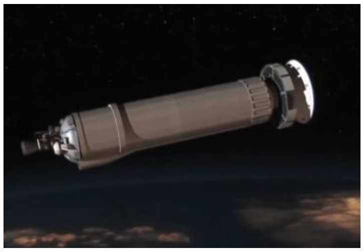


Students will designate representatives of their team to present their poster boards to evaluators. Presenters should practice good communication skills including speaking clearly and confidently, maintaining eye contact, and knowing their project thoroughly.

Centaur Essay

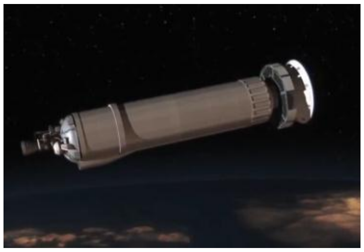
Each team will be required to compose a 500-word essay, outlining the significance of NASA's Centaur upper-stage rocket which should be included in the Tri-Fold poster. This essay should be typed in 12-point font with one-inch margins. It should have a strong introduction and conclusion, and be free of spelling or grammatical errors. It should concisely answer all of the following questions:

1. What is the historical significance of Centaur?



Centaur 50th Anniversary Engineering Design Challenge "Pushing the Limits"

2. What made the Centaur such a unique design?
3. Highlight one successful NASA mission that was accomplished with the assistance of a Centaur rocket. What were the mission's goals?
4. How does Centaur's design still impact us on Earth today?



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NASA Education Pre/ Post-Assessment

In order for NASA to provide evidence of educational impact of this challenge, we ask that you administer the following short pre and post-assessment of the same questions to measure the growth of your students.

Centaur 50th Anniversary Design Challenge Student *Pre-Assessment*

1. Which NASA center was the Centaur Rocket developed and perfected?

____

2. What made the Centaur Rocket so unique compared to other rockets?

____

____

3. Do you know the steps of the "Engineering Design Process"?

____

Centaur 50th Anniversary Design Challenge Student *Post-Assessment*

1. Which NASA center was the Centaur Rocket developed and perfected?

____

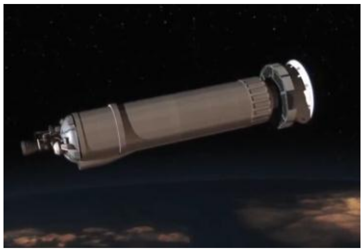
2. What made the Centaur Rocket so unique compared to other rockets?

____

____

3. Do you know the steps of the Engineering Design Process?

____



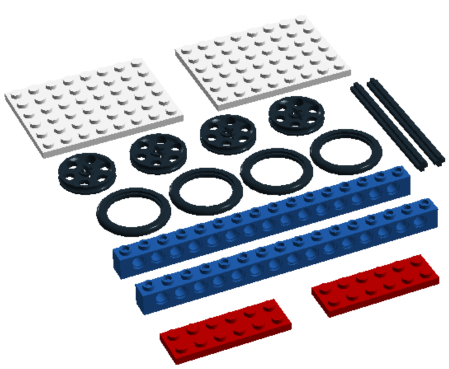
Centaur 50th Anniversary Engineering Design Challenge "Pushing the Limits"

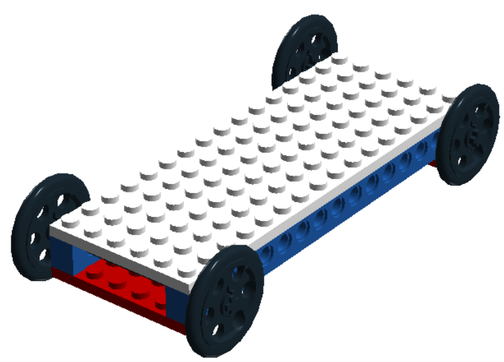
Optional Base Vehicle Assembly

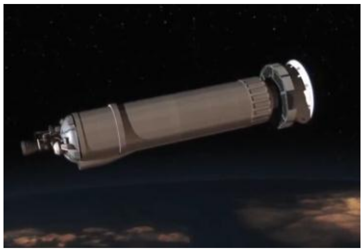
Two key challenges for creating a successful balloon-propelled rocket vehicle are minimizing the frictional forces between the vehicle and the floor, and also how to control the way the vehicle will be steered. Vehicle's steering. To eliminate these issues from the beginning of the design process, we are recommending the use of a base vehicle assembly, which will allow teams to focus their efforts on perfecting the mid-course correction capabilities. The parts listed below can be ordered from Lego.com which will allow the teams to create a simple base vehicle that can be incorporated in their overall vehicle design. This base unit is optional and not a required component.

The cost of this base unit through LEGO.com is approximately $10.00 per vehicle. A detailed instruction sheet of how the base unit can be assembled can be found by clicking on the link titled "Base Lego Unit" at http://www.nasa.gov/content/centaur-design-challenge/

Lego Part #	Description	Qty per vehicle
303601	8x6 Plate, White	2
4648532	Wedge-Belt Wheel, Black	4
281526	Tire for Wedge-Belt Wheel, Black	4
373726	Cross Axle 10M, Black	2
370323	Brick 1x16, Blue	2
4582843	Plate 2x6 w holes, Red	2





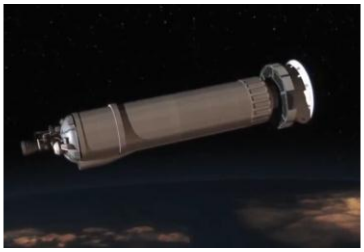


Centaur 50th Anniversary Engineering Design Challenge "Pushing the Limits"

Assessment Rubric (Tri-Fold Poster and Essay)

Team Name: ___________________________ School: ____

	Developing (1)	Approaching (3)	Meeting (5)	Score
Poster Board				
Required Elements	Poster is missing one or more steps of the engineering design process.	All steps of the engineering design process are included, but one or more steps are missing ties to the group's design.	Each step of the engineering design process is highlighted sequentially and specifics of the design are clearly defined.	
Visual Aids (charts, tables, photos and illustrations)	Visual aids are absent, are confusing, or detract from the group's poster presentation.	Most visual aids contribute positively to the poster. One or more visuals seem to be placed haphazardly.	All visual aids are appropriately placed, and contribute positively to the design explanation	
Aesthetics	Poster is disorganized, sloppy, or falling apart.	Poster is organized and is understandable. It is neatly handwritten with minimal smudges or erasure marks.	Poster is expertly organized and very easy to follow. Poster is cleanly typewritten and uniform.	
			Total Poster Board Score	
Written Essay				
History/Significance of Centaur	Element is missing	Element is present but is minimally discussed.	Essay concisely explains the history of rocket.	
Uniqueness of Centaur	Element is missing	Element is present but is minimally discussed.	Essay concisely explains features of Centaur that were new and unique.	
Centaur-launched Mission Highlight	Element is missing	Element is present but is minimally discussed.	Essay highlights a NASA mission that used the Centaur rocket to launch.	
Relevance to Today's Society	Element is missing	Element is present but is minimally discussed.	Essay defines how the Centaur has contributed to everyday life.	
Writing Mechanics	Essay has many spelling and grammatical errors. It lacks structure or organization.	Essay has minimal spelling or grammatical errors. It lacks a strong introduction or conclusion, or it exceeds 500-word limit.	Essay has no spelling or grammatical errors. It has an introduction and conclusion supported by the body of the essay.	
			Total Written Essay Score	
Poster Presentation				
Evidence of Expertise	Presenters read directly from notes or slides. Students answered questions incorrectly or did not answer questions about the project.	Students presented investigation with notes or other visuals for support. Students answered questions with hesitation or uncertainty.	Presented confidently with little help from notes. Presenters were able to confidently and accurately answer questions about the investigation.	
Verbal Skills	Presenters mumbled or were otherwise inaudible. Presenters used filler words ("um", "like", "you know", etc.) enough to be distracting.	Presenters were mostly loud and clear; only one point was difficult to hear. Presenters resorted to filler words infrequently but it did not detract from presenting.	Presenters spoke clearly and loud enough to be heard. Presenters avoided the use of filler words.	
Eye Contact	Presenters spent most of the conversation looking down or away from those speaking with them.	Presenters, at one point, looked down or away at something distracting.	Presenters maintained eye contact with those speaking with them.	
			Total Poster Presentation Score	

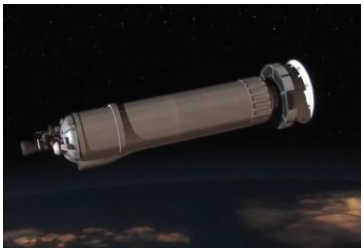


Centaur 50th Anniversary Engineering Design Challenge "Pushing the Limits"

Assessment Rubric (Design Challenge)

Team Name: ________________________ School: ______________________________

	Developing (1)	Approaching (3)	Meeting (5)	Score
Design Challenge Solution				
Rocket vehicle meets dimensional requirements	Entire vehicle (not including any balloons) does not fit within a 15-centimeter by 25-centimeter perimeter, and cannot hold a payload of 25 grams in a standard 3-ounce paper cup.	Entire vehicle (not including any balloons) does not fit within a 15-centimeter by 25-centimeter perimeter, or cannot hold a payload of 25 grams in a standard 3-ounce paper cup.	Entire vehicle (not including any balloons) fits within a 15-centimeter by 25-centimeter perimeter and can hold a payload of 25 grams in a standard 3-ounce paper cup.	
Vehicle capability to Start, Stop, then Start again	Vehicle does not start from launch area.	Vehicle effectively starts from the launch area and stops, but does not restart.	Vehicle effectively starts from the launch area, stops, then starts again	
Mid-Course Correction (bonus for autonomous)	No mid-course correction is completed.	Mid-course correction is completed before the vehicle comes to a complete stop.	Mid-course correction is completed after the vehicle comes to a complete stop and before it is restarted. ***Score double (10) if mid-course correction is completed without touching the vehicle.***	
Staying on Playing Field	Vehicle does not start completely within the launch area, **or** leaves the Challenge field **or** makes contact with Earth after launch (2+ violations)	Vehicle does not start completely within the launch area, **or** leaves the Challenge field **or** makes contact with Earth after launch (1 violation)	Vehicle starts completely within the launch area, does not leave the Challenge field and does not make contact with Earth after launch.	
Reaching Rendezvous Point	When the vehicle finally stops, any part of the payload sits outside of the outer-most ring of the Rendezvous Point. No score (0) if no part of the payload reaches the Rendezvous Point.	When the vehicle finally stops, any part of the payload sits over the second-outer-most ring of the Rendezvous Point.	When the vehicle finally stops, any part of the payload sits over the second-inner-most ring of the Rendezvous Point. *Score double (10) if any part of the payload sits above the center circle.*	
			Total Design Challenge Solution Score	
Design Innovation				
Good use of resources	Design solution demonstrates some effective use of resources.	Design solution demonstrates considerably effective use of resources.	Design solution demonstrates exceptionally effective use of resources.	
Originality	Solution utilizes a basic design to accomplish challenge goals.	Solution utilizes an enhanced design to accomplish challenge goals.	Solution utilizes a very novel design to accomplish challenge goals.	
Aesthetic	Design could use some improvement in terms of visual aesthetics.	Design is aesthetically pleasing.	Design is visually stunning and dramatic.	
			Total Design Innovation Score	
			Total From First Page	
			OVERALL SCORE	



Centaur 50th Anniversary Engineering Design Challenge "Pushing the Limits"

Optional Classroom Activities and Resources

Classroom Activities

Air- Powered Mass

Student teams build a **mass car** and measure its movement in relation to the amounts of mass it carries as it is propelled by a uniform blast of air.. Following data collection, students graph and discuss their results and compare it to the video of a similar experiment performed on the International Space Station.
http://education.ssc.nasa.gov/pdf/mvw/MVW_Air_Powered_Mass_Activity.pdf

Rocket Races

Students construct balloon-powered racing cars using a foam tray and drinking straws. They then test the cars along a measured track on the floor. At the conclusion of the activity, students submit a detailed report on their racing design and how it performed in the trials.
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Rocket_Races.html

Newton Cars

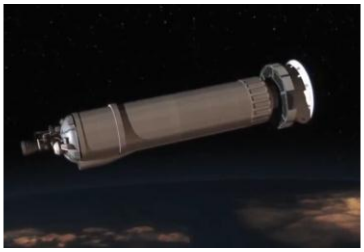
Student teams use a wooden car and rubber bands to toss a small mass off the car. The car, resting on rollers, will be propelled in the opposite direction. During a set of experiments, students will change variables. They will then measure how far the car rolls in response to the action force generated car.
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Newton_Car.html

Space Place: Make a Balloon Powered Nanorover

Design and build a robotic rover with cardboard and a balloon**.**
http://www.nasa.gov/pdf/544869main_E3_Nanorover_C2.pdf

Informational Resources

- Centaur: America's Workhorse in Space
  http://www.nasa.gov/centers/glenn/about/history/centaur.html
- Centaur Launched a Generation of Interplanetary Missions
  http://www.nasa.gov/centers/glenn/about/history/centaur_anniv.html
- Taming Liquid Hydrogen: The Centaur Upper Stage Rocket 1958 – 2002
  http://history.nasa.gov/SP-4230.pdf



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- Engineering/Exploration Design Challenge Design Packet for Middle/High School
  http://www.nasa.gov/pdf/716281main_EDC_Design_Packet_6-12.pdf